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The Faintest Star Forming Galaxies

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1. X-rays from the radio sub-mJy galaxies: two megaseconds of *Chandra* in the HDFN

We searched for X-ray detections of star forming galaxies at high redshift in the 2 Ms *Chandra* observation of the Hubble Deep Field North (HDFN). Star forming galaxies with $0.2 \lesssim z \lesssim 1.3$ were selected from the deep radio surveys in the HDFN (Richards et al. 1998, AJ 116, 1039; Richards 2000, ApJ 533, 611; Garrett 2000, A&A 361, L41); our selection criterium has been to include all galaxies with Spiral or Irregular morphologies, known redshifts and no AGN signatures in their optical spectra. From a preliminary data reduction, ten sources were detected in the X-rays; for them we determined rest-frame 0.5-2.0 and 2.0-10 keV fluxes and best-fit X-ray slopes with the same method described in Ranalli et al. (2002, A&A in press).

X-ray and radio fluxes and luminosities (Fig. 1) of these 10 high redshift objects follow the same linear relation which holds for nearby galaxies and allows the use of the X-ray luminosity as a Star Formation Rate indicator (Ranalli et al. 2002, Proc. Symp. "New Visions of the X-ray Universe", ESTEC 2001, *astro-ph/0202241*). With fluxes of the order of a few 10^{-17} erg s^{-1} cm^{-2}, these are the faintest normal galaxies ever detected in the X-rays.

2. X-ray number counts and background

We consider the number counts for the radio sub-mJy population associated with faint blue galaxies at high redshift ($22 \lesssim V \lesssim 27$, $0.5 \lesssim z \lesssim 1.5$) representing an early era of star formation in the universe. The deepest radio surveys (at 5 GHz: Fomalont et al. 1991, AJ 102, 1258; at 1.4 GHz: Richards 2000) give the Log N–Log S for this population.

Under the assumption that all the objects are placed at the same redshift (so that K-corrections are the same), the radio Log N–Log S can be converted to X-ray counts via the radio/X-ray relation. We find that the number counts of star forming galaxies should overcome AGN counts at fluxes of the order 10^{-17} erg s^{-1} cm^{-2}. Our prediction for the soft X-ray counts is fully consistent with the constraints from fluctuation analysis in the deepest *Chandra* fields (Miyaji & Griffiths 2002, ApJ 564, L5).

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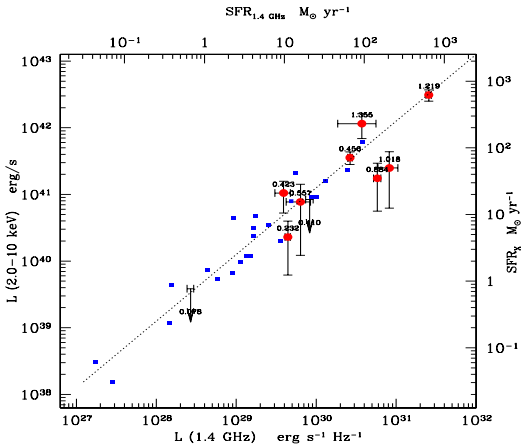

Fig. 1. The radio/X-ray luminosity relation for galaxies in the Hubble Deep Field (circles; redshifts are superimposed). Squares: nearby galaxies ($z < 0.01$) from Ranalli et al. (2002). Dotted lines: best fit relations for nearby galaxies. The same relation also holds for fluxes.

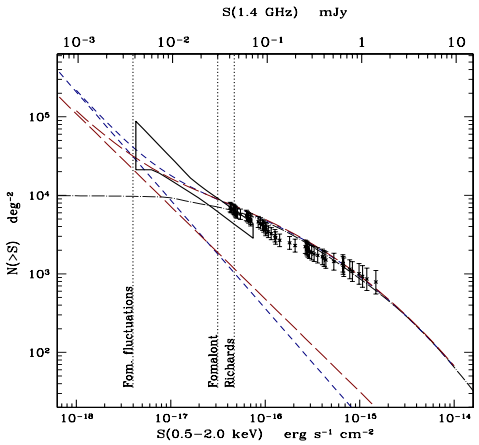

Fig. 2. X-ray counts derived from deep radio Log N–Log S. The blue short-dashed and red long-dashed straight lines represent X-ray counts derived from the 1.4 GHz (Richards 2000) and 5 GHz (Fomalont et al. 1991) Log N–Log S respectively. Dots: observed X-ray number counts in the 1 Ms *Chandra* HDFN survey (Brandt et al. 2001, AJ 122, 2810). Horn-shaped symbols: results from X-ray fluctuation analysis (Miyaji & Griffiths 2002). Dot-dashed line: number counts from AGN synthesis models (Comastri et al. 1995, A&A 296, 1). Vertical dotted lines: limiting sensitivities for the radio surveys. The sum of galaxies and AGN counts is also shown.